175. Model Studies for the Coenzyme-B_{12}-Catalyzed Methylmalonyl→Succinyl Rearrangement. The Importance of Hydrophobic Peripheral Associations

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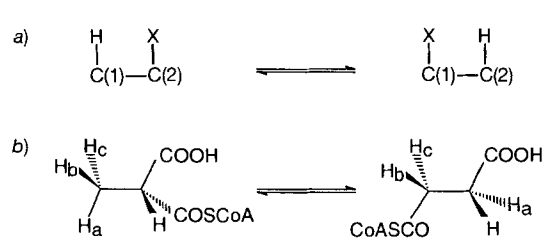
The interaction between a vitamin B_{12} derivative containing a peripheral C_{18} alkyl chain (see **1a**) and a (methyl)thiomalonate substrate bearing alkyl chains of various length at the thioester group (see **5**) was investigated. A catalytic cycle was established for the methylmalonyl→succinyl rearrangement by using electrochemistry and photolysis (see *Scheme 3*). Increased yields of the succinate relative to the reduction product were obtained (2:3 ratio), when the reaction was run in MeOH/H_2O, and when both the substrate and the catalyst had an octadecyl substituent capable of hydrophobic interactions.

Introduction. – Adenosylcobalamin acts as coenzyme for a series of biological rearrangements where a group X and a H-atom exchange places on adjacent C-atoms (*Scheme 1a*). There are twelve known reactions following this general scheme where the group X is a hydroxy, an amino or, in the C-skeleton rearrangements, a thioester, an acrylate, or a glycinate moiety. From all these reactions, only the one involving the methylmalonyl→succinyl transformation (*Scheme 1, b*) occurs in higher organisms and mammals, all the other examples being part of bacteria metabolism. In the particular case of a thioester group, the methylmalonyl-CoA mutase catalyzes the 1,2-migration with retention of configuration [1].

Scheme 1



The mechanism of the vitamin-B_{12}-dependent rearrangements has been studied enzymatically [2] and through models[1]). Although the mechanism has not yet been established in a definitive way, the enzymatic studies have provided convincing evidence for a general mechanism. This mechanism encompasses the following sequence of steps [1b]: *a*) ho-

[1]) For recent references to model reactions for methylmalonyl-CoA mutase, see [3].

molytic cleavage of the Co–C bond of the coenzym B_{12} to generate a Co^{II} complex and a 5′-deoxyadenosyl radical; *b*) abstraction of a H-atom from the substrate to generate a substrate radical and 5′-deoxyadenosine; *c*) rearrangement of the resulting substrate radical to the corresponding product radical *via* reaction channels to be established; *d*) abstraction of a H-atom from the 5′-position of 5′-deoxyadenosine by the product radical with cocomitant regeneration of the 5′-deoxyadenosyl radical to complete the rearrangement reaction.

The electronic requirements and the mechanism of the rearrangement step itself, *i.e.*, the 1,2-migration of the group X are still not well understood and present some controversial aspects. It has not yet been established whether the reorganization proceeds *via* a radical or anionic mechanism, and whether or not the Co-atom participates in the rearrangement process. *Finke* [1c] has pointed out that in the methylmalonyl mutase case, Co participation might provide some rate advantages *via* carbanion formation. On the other hand, a radical mechanism is supported by EPR studies, particularly by the observation of EPR signals for the enzymatic reaction catalyzed by methylmalonyl mutase [4]. For the methylmalonyl→succinyl rearrangement, *Golding*, *Buckel*, and coworkers have recently provided evidence for a mechanism which involves fragmentation of the substrate-derived radical into acrylate and the formyl-CoA radical, and formation of the product radical by addition of the latter to the β-position of the acrylate [5][2]). This mechanistic pathway is compatible with the stereochemistry of the skeleton rearrangements catalyzed by the glutamate mutase and the α-methyleneglutarate mutase. The enzymatic mechanism is now accepted to proceed *via* protein-bound radicals, and the naturally occurring apoproteins are considered to play an important role for desolvation and close association of the reacting species [7]. *Retey* [8] has introduced the concept of 'negative catalysis' to explain the role of enzymes in reactions involving highly reactive intermediates.

To understand the mechanism of action of a particular enzyme, many parameters must be known. These include the structure of the active site and the enzyme-substrate complex, the specificity of the enzyme and its ability to bind to the substrate, the kinetics for the various steps, and a knowledge of possible intermediates along the reaction coordinate. Complementary to this analysis are enzyme models which attempt to mimic key parameters of the enzyme function on a structural and mechanistically more transparent level. This can be achieved by synthetic organic molecules with functionalities appropriate to one or several features of an enzymatic system. Modification of the functionalities allows to study the structural requirements for efficient reactivity. In this way, enzyme models help to understand the complex structures of biomolecules and their exact *in vivo* function [9]. The ability to reconstitute the key features of an enzymatic reaction by model systems is an important step for the understanding of enzyme reactivity on a rather sophisticated level.

Model studies of the vitamin-B_{12}-induced rearrangements have primarily been concerned with the substrate stereoselectivity [1] and the electronic requirements of the rearrangement steps [1] [3]. Many model systems mimicking the rearrangement step have been developed where a radical appropriately substituted for rearrangement is generated by cleavage of a Co–C bond. *Keese*, *Kochi*, and coworkers were the first ones to detect the presence of rearranged products when methylmalonyl radicals were generated by ther-

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[2]) For a computational analysis of a mechanistic scheme involving fragmentation-addition, see [6].

molysis from corresponding peresters. Under these conditions, the thiosuccinate was detected in *ca.* 0.1% yield [10]. Subsequently, *Wollowith* and *Halpern* [11], and *Beckwith* and coworkers [12] have shown that a 'thiomalonylmethyl' (= 3-alkoxy-2-[(alkylthio)-carbonyl]-3-oxopropyl) radical can rearrange when generated from C–Br bonds with R_3SnH in the absence of Co-catalysts. *Wollowitz* and *Halpern* determined the rate of the radical rearrangement to be 2.5 s^{-1} with yields of the rearrangement product in the range of 1–9%.

More recently, models have been developed which allow for molecular recognition between the appropriately modified vitamin B_{12} catalyst and substrates. *E.g.*, *Murakami* and coworkers have reported that vitamin B_{12} derivatives, incorporated into single-compartment vesicles or *para*-azacyclophane will induce 1,2 migration of acetyl, cyano, and carboxylic-ester groups. The results are explained by suppression of molecular motion and desolvation effects taking place in the vesicle; migration is reported not to take place in the absence of the hydrophobic pocket [13a]. Earlier, *Fountoulakis* and *Retey* had developed a model where hydrophobic interactions between methylmalonates bearing a naphthyl moiety and cholestano-cobaloximes increased the yields of rearrangement products [13b].

Hydrophobic interactions are probably the most important single factor providing the driving force for noncovalent intermolecular associations in aqueous solutions and are considered to play an important role in enzymatic reactions. The binding of substrates to the active site of enzymes are attributed in a large part to hydrophobic interactions. The hydrophobic effect is also a major contributor to the tertiary structure of globular proteins, where charged and other hydrophilic groups are located at the surface whereas the hydrophobic amino-acid side chains are buried in the interior [14]. Biomimetic structures involving cyclodextrins and micelles are well-known examples where hydrophobic interactions are the main forces responsible for binding the interacting species [9].

We have developed several models for the methylmalonyl mutase reaction with the aim to investigate the impact of molecular recognition between vitamin B_{12} and the substrate on the efficiency of the rearrangement. We report here results of the 'hydrophobic model', which clearly indicate that molecular recognition between substrates and the catalyst can play an important role[3]). To generate hydrophobic interactions, long alkyl chains were introduced into the vitamin-B_{12}-derived catalyst and the (methyl)thiomalonates. The catalyst and the substrates were submitted to reaction conditions, which allow the unambiguous formation of a (methyl)thiomalonate-derived 3-alkoxy-2-[(alkylthio)carbonyl]-3-oxopropyl radical and the control of the redox reaction Co^{II}/Co^{I}. The hydrophobic interactions between the catalyst and the substrate could be modulated by an appropriate choice of solvents.

Results and Discussion. – Upon electrochemical reduction of the Co^{II} complex **1a**, the Co^{I} is alkylated by a (bromomethyl)thiomalonate such as **5a**. Homolysis of the Co–C bond by irradiation with visible light gives Co^{II} and a (methyl)thiomalonate-derived 3-alkoxy-2-[(alkylthio)carbonyl]-3-oxopropyl radical. This radical can either rearrange to a succinate-derived radical, or can be reduced to methylmalonates, or, in the presence of O_2, lead to fragmentation products [16]. Under our anaerobic reaction conditions, only

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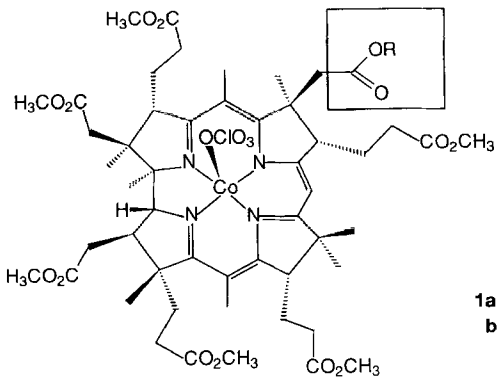
[3]) A preliminary account of some of the work reported in this paper has appeared: [15].

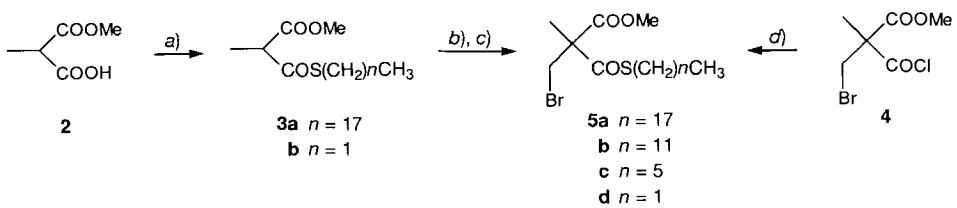
products of rearrangement and reduction are observed. The association between the long alkane chain in the catalyst and the substrate in an aqueous solvent will keep the radical in the vicinity of the Co and in a hydrophobic environment. It is thus prevented from diffusing into the bulk solvent where it could quickly abstract a H-atom. It, therefore, will have a sufficiently long life time to undergo rearrangement.



1a R = $CH_3(CH_2)_{17}$
b R = CH_3

The Co complexes **1a** and **1b** used as catalysts were readily prepared from vitamin B_{12} by known procedures [17] [18]. The synthesis of the thioesters **5a–d** (from **2** *via* **3** or from **4**) used as substrates is outlined in *Scheme 2*.

Scheme 2



2

3a $n = 17$
b $n = 1$

5a $n = 17$
b $n = 11$
c $n = 5$
d $n = 1$

4

a) DCC, 4-(dimethylamino)pyridine, $CH_3(CH_2)_nSH$ ($n = 1, 17$). *b*) NaH, DMSO. *c*) CH_2Br_2. *d*) $CH_3(CH_2)_nSH$ ($n = 5, 11$), Et_3N.

First the redox behavior of the Co complex **1a** in $MeOH/H_2O$ was investigated by cyclic voltammetry. Since the redox behavior of Co in vitamin B_{12} derivatives is primarily controlled by the electron-donating properties of the corrin-ring system, the redox potential of cobesters are similar to that of the naturally occurring vitamin B_{12} [19]. The redox potential for the Co^{II}/Co^{I} couple of **1a** is observed at −0.69 V (*vs.* SCE) which is similar to the value obtained in pure MeOH (*Fig. 1a*). The large oxidation current for $Co^{I} \rightarrow Co^{II}$ indicates that the complex is adsorbed on the glassy carbon electrode [20]. With a large excess of bromide **5a**, an irreversible reduction peak appears at −1.05 V indicating reductive cleavage of the complex **6a**, which is generated by the reaction of the Co^{I} species with the alkyl bromide **5a** (*Fig. 1b*).

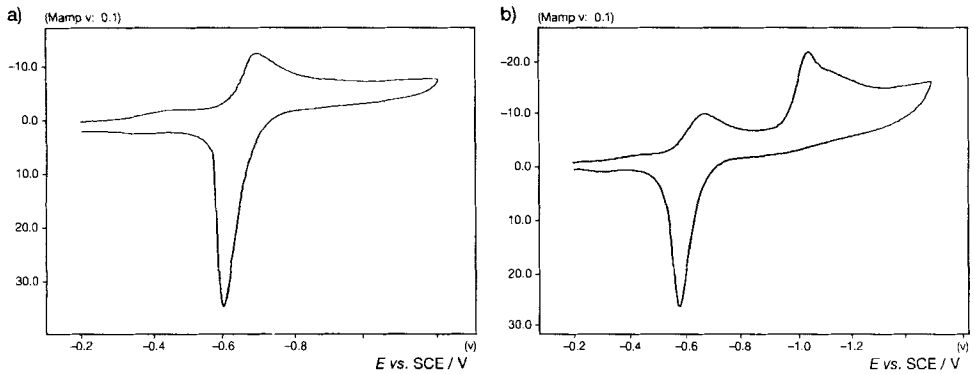


Fig. 1. *Cyclic voltammogram of* a) *complex* **1a** ($9.9 \cdot 10^{-4}$ M) *and* b) *complex* **1a** ($9.9 \cdot 10^{-4}$ M) *in the presence of bromide* **5a** ($1.6 \cdot 10^{-2}$ M) *in MeOH/H_2O 4:1 with 0.1 M $LiClO_4$*. Sweep rate 100 mV · s^{-1}.

In the catalytic cycle used in our study of the influence of the hydrophobic association between the catalyst **1** and the substrate **5** on the rearrangement step, a potential of −0.85 V was applied (*Scheme 3*). This allows the fast reduction of Co^{II} to Co^{I} which reacts readily with the bromides **5** to generate alkyl-Co complexes **6** (see below). The potential set at −0.85 V enables reduction of Co^{II} to Co^{I} to occur readily but is too positive to trigger reductive cleavage of the C–Co bond. The C–Co bond in the alkyl-Co complexes **6** is homolytically cleaved by irradiation with a 150-W lamp to form unambiguously the radical and to regenerate the Co^{II} species. The latter is reduced again to Co^{I} and initiates a new catalytic cycle. The products **7** and **8** derived from the radical formed by photolytic cleavage of the C–Co bond were analyzed by GC (with co-injection of authentic samples under standardized conditions) and GC/MS.

Variations in the reaction parameters were made to assess the effect of the noncovalent associations between the substrate and the catalyst on the ratio of reduced and rearranged products **7** and **8**, respectively. The results obtained are summarized in *Tables 1–3*. Thus the amount of the rearrangement product **8a** is larger when both the catalyst and the substrate bear a C_{18} alkyl substituent, and the reaction medium is MeOH/H_2O (*Table 1*). Under these conditions (*i.e.*, catalyst **1a**), **7a** and **8a** are formed in a 1.3:1 ratio and yields of 28 and 22% respectively, the bromide **5a** being recovered in 38% yield. The absence of a long alkyl chain in the catalyst (see **1b**) results in a sluggish reaction with low yields and poor reproducibility. This can be explained by the absence of aggregate formation between catalyst **1b** and substrate **5a** in MeOH/H_2O; by contrast, aggregation of **1a** and **5a** is more favorable. A blank experiment confirms that rearrangement occurs only in the presence of **1a**: after 18 h in the absence of the catalyst, **5a** is recovered under the applied potential and irradiation. In view of the observation that **1a** is adsorbed on the glassy carbon electrode apparent in the CV measurements, it cannot be excluded that the carbon felt used as cathode in the catalytic reactions is involved in the association (see below).

Variation of the solvent (*Table 2*) changes the product distribution dramatically. Whereas in MeOH/H_2O reduced and rearranged products **7a** and **8a** are obtained in a 1.3:1 ratio and good yields, bromide **5a** is not stable in pure MeOH under

Scheme 3

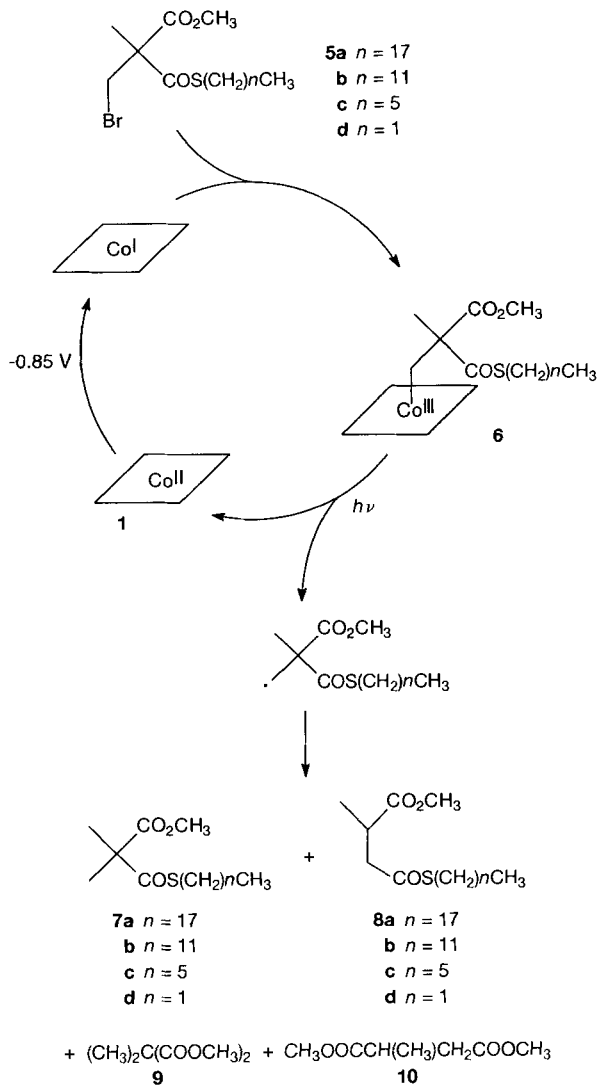


Table 1. *Catalytic Cycle with* **1a,b** (R = $Me(CH_2)_{17}$, Me) *as Catalyst and* **5a** (*n* = 17) *as Substrate: Product Distribution in Relationship to the Length of the Alkyl Group in* **1**[a])

Catalyst	Product ratio (yield [%])		
	7	**8a**	**5a**
1a (R = $Me(CH_2)_{17}$)	1.3 (28)	1 (22)	38
1b (R = Me)	1.5 (2–6)	1 (3–11)	45–56
No catalyst	trace	–	recovered

[a]) 5% of catalyst **1**, MeOH/H_2O 4:1 as solvent, and **5a** as substrate; yields and ratios determined by GC.

the reaction conditions, and none of the products obtained in $MeOH/H_2O$ can be detected. Dioctadecyl disulfide is isolated from the reaction mixture indicating cleavage of the thioester. It can also be seen that the $MeCN/H_2O$ mixture does not favor rearrangement to the same extent as $MeOH/H_2O$ does. In this case, the ratio **7a**/**8a** increases to 10:1. In pure MeCN the ratio **7a**/**8a** is 4:1, but the mass balance is reduced to 39% (two independant runs). To clarify this result, further investigations of the reaction in MeCN have to be undertaken.

Table 2. *Catalytic Reaction with* **1a** ($R = Me(CH_2)_{17}$) *as Catalyst and* **5a** ($n = 17$) *as Substrate: Effect of the Solvent on the Product Distribution*[a])

Solvent	Yield [%] of products		
	7a	**8a**	**5a**
$MeOH/H_2O$ 4:1	28	22	38
MeOH	trace	–	–
$MeCN/H_2O$ 2:1	32	3	26
MeCN	12	3	24

[a]) 5% of **1a** as catalyst and **5a** as substrate; yields determined by GC.

Shortening of the alkyl chain of substrate **5a** ($n = 17$) by 6 CH_2 groups is sufficient to shift the product distribution towards reduction, the ratio **7b**/**8b** being 18:1 when substrate **5b** ($n = 11$) and catalyst **1a** with the C_{18} side chain is used (*Table 3*). This indicates a looser interaction between the C_{12} and C_{18} than between the C_{18} and C_{18} alkyl chains [21]. When the alkyl chain of **5** is a hexyl (**5c**) or ethyl group (**5d**), the reaction takes a different course. Reduction (→ **7c**,**d**) and the formation of the dimethyl esters **9** and/or **10** are observed. However, when dimethyl 2-(bromomethyl)-2-methylmalonate is the substrate, no rearrangement at all is observed, dimethyl dimethylmalonate (**9**) being the only product detected. This indicates that the rearranged dimethyl ester **10** is formed prior to methanolysis of the thioester. The results obtained clearly show the importance of hydrophobic interactions for the enhancement of rearrangement.

Table 3. *Catalytic Reaction with* **1a** ($R = Me(CH_2)_{17}$) *as Catalyst and* **5a**,**b**,**c**,**d** ($n = 17, 11, 5, 1$) *as Substrate: Effect of the Alkyl Chain Length in* **5** *on the Product Distribution*[a])

Substrate	Product ratio				
	7	**8**	**9**	**10**	**5**
5a ($n = 17$)	1.3	1	–	–	2
5b ($n = 11$)	18	1	1	2	–
5c ($n = 5$)	5	–	–	1	–
5d ($n = 1$)	1.4	–	1	2.3	–

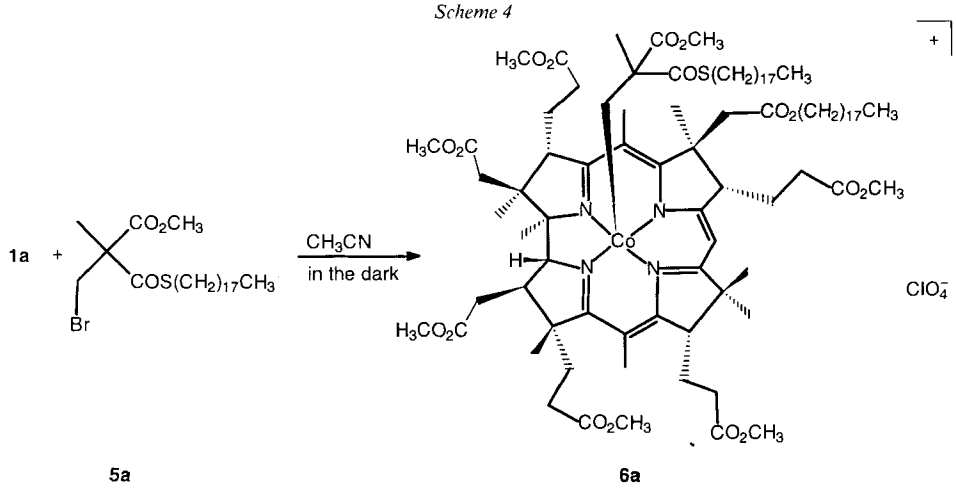
[a]) 5% of **1a** as catalyst and $MeOH/H_2O$ 4:1 as solvent; ratio of products determined by GC.

To gain insight into the nature of the species formed by rearrangement under the applied conditions, the reaction of substrate **5a** with catalyst **1a** was carried out in deuterated solvents. In CH_3OD/D_2O solution, 1 D is incorporated in the succinate **8a**, but no D is present in the reduced product **7a**. With CD_3OH/HO as solvent, there is no

incorporation of D in either one of the products. When a mixture of **5a**, **7a**, **8a** is stirred overnight in CH_3OD/D_2O 4:1, no deuterium incorporation in **8a** is observed by GC/MS, indicating that H/D exchange does not take place. These surprising results suggest that the succinate is formed by uptake of H^+ rather than $H^\cdot$ and that at least in a later stage of the transformation of the (methyl)thiomalonate-derived radical, an anion is formed. The fact that no D incorporation takes place in the reduction product suggests that the substrate is part of an aggregate which keeps solvent molecules away from the radical long enough. The latter could then abstract a H-atom from the lipophilic side chains around it with no incorporation of D^+ from the methanol. It should be noted that in the model studies of the same vitamin-B_{12}-catalyzed rearrangement conducted by *Scott* and coworkers [3k], and *Dowd* and coworkers [3j], run under conditions where anions could have formed, D incorporation was observed in both the rearranged and reduced products.

In our mechanistic scheme, complex **6a**, formed by alkylation of reduced **1a** with the bromide **5a**, should be an intermediate in the catalytic cycle. Consequently, we have prepared the alkylated complex **6a**: Co^{II} perchlorate **1a** is electrochemically reduced to Co^{I} in MeCN at −1.0 V and reacted with bromide **5a** in the dark to give perchlorate **6a** (*Scheme 4*). This complex is obtained in 40% yield and fully characterized by its ^{1}H- and ^{13}C-NMR spectra and FAB-MS.

Scheme 4



5a **6a**

The ^{1}H-NMR of **6a** (*Fig. 2*) shows two signals for several of the protons. *E.g.*, the resonances at 6.97 and 6.93 ppm can be assigned to H–C(10) of the corrin ring (the ^{1}H-NMR assignments are made by analogy with known vitamin B_{12} derivatives [22]). This is due to formation of the two diastereoisomers expected for the reaction of the racemic bromide with the enantiomerically pure vitamin B_{12} derivative. The two compounds are formed by coordination on the β-side of the corrin ring. Confirmation that the two compounds are diastereoisomers and not coordination isomers formed by reaction of the Co on the α- and the β-side of the corrin ring are obtained by NOE (TROESY) experiments. Irradiation at the frequency of the *d* at 4.61 ppm (H–(19)) produces an enhancement of the signal at 2.1 ppm assigned to 1 H of the CH_2 group bonded to Co. Analogously, irradiation of the other H–C(19) at 4.67 ppm shows an interaction with the signal at 2.5 ppm, assigned to 1 H of the CH_2 group of the other diastereoisomer. In the inverse experiment, irradiation at 2.1 and 2.4 ppm leads to more intensive peaks at 4.61 and 4.67 ppm and, due to the strong geminal interaction, to enhanced signals for the diastereotopic H's at 0.34 and 0.59 ppm. The ^{13}C-NMR spectrum presents the expected number of C-atoms. Since the two diastereoisomers are formed in a ratio of 1:1, stereoselectivity in the formation of **6a** under our reaction conditions is essentially absent.

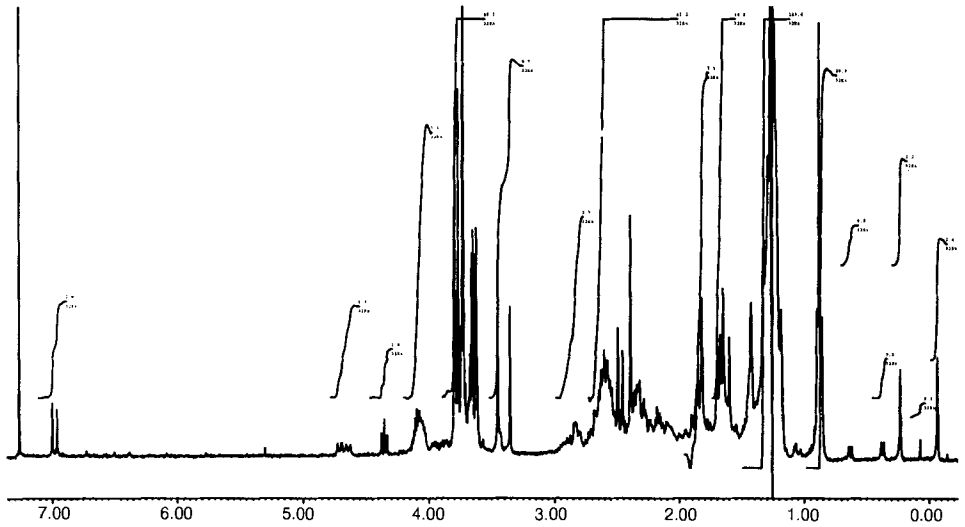


Fig. 2. *^{1}H-NMR Spectrum of* **6a**

The isolated complex **6a** was placed in MeOH/H_2O 4:1 and irradiated with a 150-W lamp at room temperature. After cooling, the ESR signal of Co^{II} was observed, whereas the (methyl)thiomalonate-derived radical was absent under these reaction conditions [23]. Only traces of rearranged **8a** were detected when **6a** was submitted to a preparative experiment. However, when complex **6a** was irradiated in the presence of 20 mol-equiv. of **5a**, a mixture of **7a** and **8a** in a 2.7:1 ratio was obtained. These results, obtained in homogeneous solution in the absence of the carbon-felt electrode, support the hypothesis that **5a** forms aggregates in MeOH/H_2O and that incorporation of **1a** into the aggregate increases the amount of rearrangement. Whether the carbon felt, used as the cathode, is also involved in the association of the catalyst **1a** and the substrate **5a** is an open question. The concentration of **1a** in a MeOH/H_2O solution remained constant, when **1a** was exposed to the carbon-felt electrode.

Conclusions. – Our studies of a model of the vitamin-B_{12}-catalyzed methylmalonyl-succinyl rearrangement established the influence of the noncovalent association of vitamin B_{12} and the substrate on the ratio of reduced and rearranged products. It is an example where molecular recognition and a catalytic transformation are coupled. A high yield of **8a** compared to **7a** (*ca.* 2:3 ratio) was obtained when the substrate and the catalyst both contain a lipophilic octadecyl moiety and the reaction is conducted in MeOH/H_2O. Further aspects like the detection of the methylmalonate-derived radical and its distance from the Co^{II} center as well as the stereoselectivity of the rearrangement will be investigated.

The authors thank Mrs. *F. P. Sun* for the preparation of reference compounds, Mr. *A. Saxer* for the GC analysis, PD Dr. *P. Bigler* for the NOE experiments, and Mr. *H. Gfeller* for GC/MS measurements. The support of this work by the *Swiss National Science Foundation* (project No. 20-37270.93), the *European Community* (Science project No. SCI*CT920798 1993–1995), and the *Heim-Vögtlin-Fonds* is gratefully acknowledged.

Experimental Part

General. The reactions were carried out with reagents and solvents of *puriss.* grade from *Fluka.* DMF (*Fluka, puriss.*) was kept over molecular sieves and DMSO distilled from CaH_2 under reduced pressure. Deuterated solvents were from Dr. *Glaser AG,* Basel: CH_3OD > 99.50 atom-% D, D_2O > 99.8 atom-% D, CD_3OH > 99.50 atom-% D. Bidistilled H_2O was used for the electrochemical experiments. Flash chromatography (FC): distilled commercial-grade solvents; silica gel (30–60 μm) from *Baker* (analyzed reagents); $NaClO_4$-impregnated silica gel was prepared by addition of $NaClO_4$ (1 g) in MeOH (100 ml) to silica gel (100 g) in MeOH (200 ml), stirring for 30 min, evaporation, and drying *in vacuo*; MPC = medium-pressure chromatography. TLC: *Merck-F-254* pre-coated sheets, visualization by $KMnO_4/H_2O$ or by UV. GC: *Hewlett-Packard HP-5890* with a flame ionization detector, *HP-3396A* integrator; 10 m × 0.2 mm capillar column with *HP-5 Ultra* as stationary phase; He as carrier gas. Cyclic voltammetry: *Amel-568* generator, *Amel-553* potentiostat, and *Graphrec-WX-2400-X-Y* recorder; working electrode: glassy carbon *Metrohm 6.0804.010*; counter electrode: platine wire (d = 1 mm); reference: SCE (*Metrohm 6.0724.000*); for catal. reactions: *Amel-567* generator, *Amel-553* potentiostat; working electrode: carbon felt (diameter 2 cm) connected to a Pt wire; counter electrode: CE Pt-foil; reference electrode: SCE. UV/VIS: *Perkin-Elmer PE 554.* IR: *Perkin-Elmer PE 782*; CHCl soln. in 0.2-mm path NaCl cells; in cm^{-1}. NMR: *Bruker-AC-300* (^1H, 300 MHz; ^{13}C, 75 MHz) and *Bruker-AC-500* (^1H, 500 MHz; ^{13}C, 100 MHz); δ in ppm rel. to $SiMe_4$; J in Hz. ^{13}C Multiplicities from DEPT spectra. MS: *Varian MAT-CH-7A,* 70 eV; in m/z (%). FAB-MS: *Vacuum Generator Micromass 7070 E* with *DS11-250* data system. GC/MS: *Varian 3700 SE-54* coupled to a *Varian MAT 44S.*

Hexamethyl c-*Octadecyl* Coβ-*Perchlorato-cob(II)yrinate* (**1a**). Hexamethyl c-octadecyl dicyanocob(III)yrinate [17] (330 mg, 0.25 mmol) in CH_2Cl_2 (50 ml) was treated with 30% aq. perchloric acid (40 ml) in an ultrasonic bath. the soln. was kept under vibration and was periodically evacuated to eliminate the HCN formed. The aq. phase was extracted with CH_2Cl_2, the combined org. phase washed with H_2O, filtered through dry cotton, and evaporated, and the crude product dissolved in toluene and precipitated by addition of the toluene soln. to hexane (50 ml). Drying under high vacuum gave 335 mg (95%) of aquocyano complex. This aquocyanocob(III)yrinate (335 mg, 0.23 mmol) was mixed with MeOH (160 ml) and H_2O (160 ml). The soln. was deoxygenated in an ultrasonic bath under Ar and then transferred to a separatory funnel. It was treated with $NaBH_4$ (3.6 g, 95 mmol) under Ar. The mixture was vigorously shaken with frequent venting. After 20 min, a dark green precipitate was formed. Deoxygenated Et_2O (200 ml) was added (→green org. phase), the aq. phase separated, and deoxygenated 30% aq. perchloric acid (50 ml) added carefully to the Et_2O soln., followed by distilled H_2O to induce separation of the two phases. The org. phase was washed with 0.1M phosphate buffer pH 7 (+1% sodium perchlorate) (50 ml), dried (Na_2SO_4), and evaporated. The residue was precipitated from toluene upon addition of hexane (50 ml): 297 mg of **1a**. The hexane layer was decanted and evaporated, and the residue was also reprecipitated from toluene/hexane: additional 29 mg of **1a**. Total yield 82%. UV/VIS ($c = 2.76 \cdot 10^{-5}$ M, CH_2Cl_2): 263 (14900), 311 (18600), 327 (sh, 14600), 396 (4800), 465 (10100). IR ($CHCl_3$): 2960*m*, 2930*m*, 2860*m*, 1735*s*, 1572*m*, 1490*m*, 1440*m*, 1355*m*, 1160*m*, 1108*m*, 1050*m*. FAB-MS (glycerol/thioglycerol; matrix $C_{69}H_{107}ClCoN_4O_{18}$, calc. 1375.01): 1277 (35), 1276 (73, $[M + H - ClO_4]^+$), 1275 (100, $[M - ClO_4]^+$), 1274 (18), 1273 (19), 1261 (15), 1201 (11), 1187 (10), 1173 (10), 1116 (10), 963 (15, $[M - ClO_4 - C_{20}H_{40}O_2]^+$), 905 (17), 877 (12), 876 (22), 802 (10). Anal. calc. for $C_{69}H_{107}ClCoN_4O_{18}$ (1375.01): C 60.27, H 7.84; found: C 59.99, H 7.96.

Heptamethyl Coβ-*Perchloratocob(II)yrinate* ([Cob(II)ester]ClO_4, **1b**) was prepared following procedures in [16] [18].

O-*Methyl* S-*Octadecyl 2-Methylmonothiomalonate* (= *Methyl 2-Methyl-3-(octadecylthio)-3-oxopropanoate;* **3a**). To methyl hydrogen methylmalonate (**2**; 1.5 g, 11.35 mmol) in CH_2Cl_2 (50 ml) under N_2 was added 4-(dimethylamino)pyridine (141 mg, 1.15 mmol). After cooling the mixture to 0°, octadecane-1-thiol (3.7 g, 12.6 mmol) and dicyclohexylcarbodiimid (DCC; 2.61 g, 12.6 mmol) were added. After 5 min, the ice bath was removed and the mixture stirred at r.t. for 18 h, then filtered through *Celite*, and evaporated. The residue was dissolved in Et_2O, washed with 1N HCl, sat. $NaHCO_3$ soln., and sat. NaCl soln. dried ($MgSO_4$), and evaporated. Purification by MPC (hexane/Et_2O 10:1) yielded **3a** (3.02 g, 66.5%). TLC (hexane/Et_2O 7:1): R_f 0.38. IR ($CHCl_3$): 2925*s*, 2855*s*, 1745*s*, 1685*s*, 1460*s*, 1440*m*, 1380*m*, 1328*m*, 1178*m*, 1108*m*, 1088*m*, 1030*m*, 980*s*, 950*s*. ^1H-NMR: 0.88 (*t*, J = 7, 3 H); 1.21–1.40 (*m*, 30 H); 1.45 (*d*, J = 1, 3 H); 1.50–1.67 (*m*, 2 H); 2.91 (*t*, J = 7.3, 2 H); 3.65 (*q*, J = 7.1, 1 H); 3.74 (*s*, 3 H). ^{13}C-NMR: 14.12 (*q*); 14.29 (*q*); 22.71 (*t*); 28.80 (*t*); 29.19 (*t*); 29.27 (*t*); 29.32 (*t*); 29.38 (*t*); 29.49 (*t*); 29.59 (*t*); 29.65 (*t*); 29.69 (*t*); 29.72 (*t*); 51.95 (*t*); 52.59 (*d*); 53.90 (*q*); 169.95 (*s*); 195.99 (*s*). MS: 400 (5, M^+), 382 (4), 285 (24), 232 (11), 115 (100), 97 (16), 87 (21), 83 (17), 69 (15), 57 (18), 55 (15). Anal. calc. for $C_{23}H_{44}O_3S$ (400.67): C 68.95, H 11.07; found: C 68.89, H 11.02.

O-Methyl S-Octadecyl 2-(Bromomethyl)-2-methylmonothiomalonate (= *Methyl 2-(Bromomethyl)-2-methyl-3-(octadecylthio)-3-oxopropanoate*; **5a**). Following the general procedure of [12], NaH (102 mg, 4.25 mmol) was washed with hexane and suspended in DMSO. A soln. of **3a** (1.5 g, 3.74 mmol) in DMSO (6 ml) was added dropwise and the suspension stirred under N_2 until no more H_2 evolution was observed. The mixture was cooled in an ice bath and CH_2Br_2 (1.24 g, 7.11 mmol) added dropwise. Then the ice bath was removed and the mixture stirred at r.t. for 16 h. It was then diluted with H_2O (40 ml) and extracted with Et_2O (3×). The combined extracts were washed with sat. NaCl soln., dried ($MgSO_4$), and evaporated. The residue was purified by MPC (hexane/Et_2O 12:1) **5a** (1.05 g, 57%). TLC (hexane/Et_2O 6:1): R_f 0.55. IR ($CHCl_3$): 3040–3020*m*, 2930*s*, 2860*s*, 1745*s*, 1675*s*, 1460*s*, 1440*m*, 1380*m*, 1285*s*, 1265*s*, 1170*m*, 1115*m*, 1070*m*, 990*m*, 968*s*, 920*s*. ^{1}H-NMR: 0.88 (*t*, *J* = 7, 3 H); 1.20–1.41 (*m*, 30 H); 1.51–1.63 (*m*, 2 H); 1.67 (*s*, 3 H); 2.93 (*t*, *J* = 7.3, 2 H); 3.75 (*d*, *J* = 10.3, 1 H); 3.78 (*s*, 3 H); 3.88 (*d*, *J* = 10.3, 1 H). ^{13}C-NMR (75 MHz, $CDCl_3$): 14.04 (*q*); 20.02 (*q*); 22.62 (*t*); 28.67 (*t*); 28.99 (*t*); 29.02 (*t*); 29.30 (*t*); 29.35 (*t*); 29.39 (*t*); 29.49 (*t*); 29.56 (*t*); 29.60 (*t*); 29.63 (*t*); 31.86 (*t*); 35.96 (*t*); 53.05 (*q*); 61.77 (*s*); 169.65 (*s*); 196.69 (*s*). MS: 494 (1, M^+), 492 (2, M^+), 461 (2), 313 (42), 286 (52), 285 (100), 284 (55), 209 (77), 207 (76), 181 (68), 179 (68), 153 (43), 151 (43), 101 (63), 99 (36), 85 (33), 71 (38), 69 (46), 59 (32), 57 (42), 55 (30), 43 (32), 41 (36). Anal. calc. for $C_{24}H_{45}BrO_3S$ (493.58): C 58.40, H 9.19; found: C 58.52, H 9.10.

S-Dodecyl O-Methyl 2-(Bromomethyl)-2-methylmonothiomalonate (= *Methyl 2-(Bromomethyl)-3-(dodecylthio)-2-methyl-3-oxopropanoate*; **5b**). Methyl 3-bromo-2-(chlorocarbonyl)-2-methylpropanoate (= methyl 2-(bromomethyl)-3-chloro-2-methyl-3-oxopropanoate; **4**) [24] (1.46 g, 6 mmol) was added dropwise to dodecane-1-thiol (1.8 g, 6 mmol) and Et_3N (2 ml) in toluene (10 ml), and the mixture was stirred under N_2 for 18 h. It was then diluted with H_2O and extracted with AcOEt (3×). The org. phase was washed with 1M HCl and sat. NaCl soln., dried (Na_2SO_4), and evaporated. The residue was submitted to FC (hexane/Et_2O 10:1): **5b** (1.1 g, 45%). TLC (hexane/Et_2O 10:1): R_f 0.44. IR: 2930*s*, 2860*s*, 1740*s*, 1670*s*, 1460*m*, 1440*m*, 1280*m*, 1260*m*, 1170*m*, 1110*m*, 1070*m*, 970*s*. ^{1}H-NMR: 0.87 (*t*, *J* = 7, 3 H); 1.25–1.36 (*m*, 18 H); 1.52–1.63 (*m*, 2 H); 1.63 (*s*, 3 H); 2.92 (*t*, *J* = 7.3, 2 H); 3.74 (*d*, *J* = 10.3, 1 H); 3.76 (*s*, 3 H); 3.88 (*d*, *J* = 10.3, 1 H). ^{13}C-NMR: 196.76 (*s*); 169.72 (*s*); 61.82 (*s*); 53.14 (*q*); 36.04 (*t*); 31.93 (*t*); 29.64 (*t*); 29.56 (*t*); 29.47 (*t*); 29.42 (*t*); 29.36 (*t*); 29.09 (*t*); 29.07 (*t*); 28.74 (*t*); 22.70 (*t*); 20.08 (*q*); 14.13 (*q*). MS: 410 (2, M^+), 408 (1.5, M^+), 242 (4), 240 (4), 229 (18), 209 (67), 207 (65), 201 (100), 181 (67), 179 (68), 153 (33), 151 (33), 128 (10), 101 (77), 85 (12), 71 (19), 69 (26), 59 (21). Anal. calc. for $C_{18}H_{33}BrO_3S$ (409.42): C 52.80, H 8.12; found: C 53.08, H 8.02.

S-Hexyl O-Methyl 2-(Bromomethyl)-2-methylmonothiomalonate (= *Methyl 2-(Bromomethyl)-3-(hexylthio)-2-methyl-3-oxopropanoate*; **5c**) was prepared in the same way as described for **5b**. After FC (hexane/Et_2O 4:1), **5c** was obtained in 50% yield. IR: 2960*s*, 2930*s*, 2860*s*, 1730*s*, 1670*s*, 1460*s*, 1440*s*, 1380*s*, 1260*s*, 1170*s*, 1115*s*, 1070*s*, 925–905*m*, 875*m*, 840*w*, 610*m*. ^{1}H-NMR: 0.88 (*t*, *J* = 7, 3 H); 1.25–1.38 (*m*, 6 H); 1.53–1.64 (*m*, 2 H); 1.64 (*s*, 3 H); 2.92 (*t*, *J* = 7, 2 H); 3.75 (*d*, *J* = 10.7, 1 H); 3.77 (*s*, 3 H); 3.88 (*d*, *J* = 10.7, 1 H). ^{13}C-NMR: 196.65 (*s*); 169.63 (*s*); 61.77 (*s*); 53.05 (*q*); 35.99 (*t*); 31.18 (*t*); 29.35 (*t*); 29.01 (*t*); 28.32 (*t*); 22.42 (*t*); 20.01 (*q*); 13.93 (*q*). MS: 326 (1, M^+), 324 (1, M^+), 227 (10), 225 (11), 218 (25), 209 (87), 207 (90), 181 (81), 179 (82), 159 (9), 158 (11), 153 (57), 151 (58), 117 (84), 101 (100), 84 (95), 69 (66), 57 (71). Anal. calc. for $C_{12}H_{21}BrO_3S$ (325.26): C 44.31, H 6.51; found: C 44.52, H 6.32.

S-Ethyl O-Methyl 2-(Bromomethyl)-2-methylmonothiomalonate (= *Methyl 2-(Bromomethyl)-3-(ethylthio)-2-methyl-3-oxopropanoate*; **5d**). From *O*-methyl *S*-ethyl-2-methylmonothiomalonate (= methyl 3-(ethylthio)-2-methyl-3-oxopropanoate; **3b**; 1.3 g, 8.5 mmol) as described [12]. FC (hexane/Et_2O 4:1) gave **5d** (906 mg, 40%).

O-Methyl S-Octadecyl 2,2-Dimethylmonothiomalonate (= *Methyl 2,2-Dimethyl-3-(octadecylthio)-3-oxopropanoate*; **7a**). As described for **5a**, by alkylation of **3a** with CH_3I: 72% **7a**. TLC (hexane/Et_2O 10:1): R_f 0.40. IR: 3030*w*, 2930*s*, 2860*s*, 1742*s*, 1680*s*, 1470*s*, 1440*m*, 1390*m*, 1370*m*, 1270*s*, 1198*m*, 1155*m*, 1025*m*, 998*m*, 968*s*, 895*m*. ^{1}H-NMR: 0.88 (*t*, *J* = 7, 3 H); 1.20–1.43 (*m*, 30 H); 1.50 (*s*, 6 H); 1.51–1.63 (*m*, 2 H); 2.88 (*t*, *J* = 7.3, 2 H); 3.73 (*s*, 3 H). ^{13}C-NMR: 14.13 (*q*); 22.71 (*t*); 23.19 (*q*); 28.83 (*t*); 29.07 (*t*); 29.12 (*t*); 29.27 (*t*); 29.38 (*t*); 29.50 (*t*); 29.59 (*t*); 29.66 (*t*); 29.71 (*t*); 31.95 (*t*); 52.65 (*q*); 57.08 (*s*); 173.02 (*s*); 200.22 (*s*). MS: 414 (26, M^+), 396 (10), 327 (28), 313 (66), 286 (63), 285 (99), 284 (52), 162 (28), 130 (32), 129 (100), 102 (86), 101 (81), 73 (41). Anal. calc. for $C_{24}H_{46}O_3S$ (414.68): C 69.51, H 11.18; found: C 69.51, H 11.29.

S-Dodecyl O-Methyl 2,2-Dimethylmonothiomalonate (= *Methyl 3-(Dodecylthio)-2,2-dimethyl-3-oxopropanoate*; **7b**). Methyl hydrogen dimethylmalonate (200 mg, 1.4 mmol) was transformed into **7b** with dodecane-1-thiol (606 mg, 2.8 mmol), 4-(dimethylamino)pyridine (16.3 mg, 0.14 mmol), and DCC (330.7 mg, 1.6 mmol) as described for **3a**. FC (hexane/Et_2O 12:1) gave **7b** (140 mg, 31%). TLC (hexane/Et_2O 8:1): R_f 0.67. IR: 2905*s*, 2850*s*, 1735*s*, 1673*s*, 1464*m*, 1433*w*, 1150*m*. ^{1}H-NMR: 0.85–0.90 (*t*, 3 H); 1.18–1.37 (*m*, 18 H); 1.48 (*s*, 6 H); 1.50–1.65 (*m*, 2 H); 2.85–2.90 (*t*, *J* = 7.35, 2 H); 3.72 (*s*, 3 H). ^{13}C-NMR: 14.08 (*q*); 22.67 (*t*); 23.16 (*q*); 28.80 (*t*); 29.05 (*t*); 29.08 (*t*); 29.23 (*t*); 29.33 (*t*); 29.46 (*t*); 29.54 (*t*); 29.62 (*t*); 31.90 (*t*); 52.63 (*q*); 57.06 (*s*); 172.99 (*s*); 200.20 (*s*). MS: 330 (2, M^+), 299 (2.5), 229 (6), 201 (27), 129 (87), 102 (60), 101 (100), 73 (66), 57 (21), 55 (20), 41 (35), 43 (32), 29 (13). Anal. calc. for $C_{18}H_{34}O_3S$ (330.53): C 65.41, H 10.37; found: C 65.40, H 10.27.

S-*Hexyl* O-*Methyl 2,2-Dimethylmonothiomalonate* (= *Methyl 3-(Hexylthio)-2,2-dimethyl-3-oxopropanoate*; **7c**). As described for **7b**. FC (hexane/Et_2O 12:1) gave 36% of **7c**. TLC (hexane/Et_2O 12:1): R_f 0.42. IR: 2920*s*, 2850*s*, 1732*s*, 1672*s*, 1466*m*, 1433*w*, 1387*w*. ^{1}H-NMR: 0.87 (*t*, 3 H); 1.20–1.40 (*m*, 6 H); 1.48 (*s*, 6 H); 1.50–1.66 (*m*, 2 H); 2.86–2.90 (*t*, 2 H); 3.72 (*s*, 3 H). ^{13}C-NMR: 13.93 (*q*); 22.45 (*t*); 23.14 (*q*); 28.42 (*t*); 29.02 (*t*); 29.17 (*t*); 31.23 (*t*); 52.59 (*q*); 57.04 (*s*); 172.97 (*s*); 200.17 (*s*). MS: 246 (3, M^+), 215 (4.5), 159 (7), 129 (63), 102 (55), 101 (100), 73 (66), 43 (35), 41 (35). Anal. calc. for $C_{12}H_{22}O_3S$ (246.36): C 58.50, H 9.00; found: C 58.43, H 8.96.

O-*Methyl* S-*Octadecyl 2-Methylmonothiosuccinate* (= *Methyl 2-Methyl-4-(octadecylthio)-4-oxobutanoate*; **8a**). As described for **3a**, with methyl hydrogen 2-methyl succinate [25] (150 mg), octadecane-1-thiol (600 mg, 2.1 mmol), 4-(dimethylamino)pyridine (12.2 mg, 0.1 mmol), and DCC (248 mg, 1.2 mmol) in CH_2Cl_2 (10 ml). MPC (hexane/Et_2O 10:1) gave **8a** (248 mg, 58%). TLC (hexane/Et_2O 10:1): R_f 0.31. IR: 2930*s*, 2860*s*, 1735*s*, 1682*m*, 1465*m*, 1175*w*, 1130*w*. ^{1}H-NMR: 0.88 (*t*, J = 7, 3 H); 1.18–1.40 (*m* + *s*, 30 resp. 3 H); 1.21 (*d*, J = 7.3, 3 H); 1.50–1.63 (*m*, 2 H); 2.65 (*dd*, J = 18.6, 9, 1 H); 2.87 (*t*, J = 7.3, 2 H); 2.92–3.06 (*m*, 2 H); 3.70 (*s*, 3 H). ^{13}C-NMR: 14.13 (*q*); 16.80 (*q*); 22.71 (*t*); 28.83 (*t*); 28.97 (*t*); 29.12 (*t*); 29.38 (*t*); 29.50 (*t*); 29.53 (*t*); 29.59 (*t*); 29.65 (*t*); 29.68 (*t*); 29.71 (*t*); 31.95 (*t*); 36.01 (*d*); 46.86 (*t*); 51.96 (*q*); 175.45 (*s*); 197.61 (*s*). MS: 414 (6, M^+), 384 (17), 383 (44), 131 (26), 130 (45), 129 (100), 101 (31), 83 (14), 71 (14), 69 (26), 59 (38). Anal. calc. for $C_{24}H_{46}O_3S$ (414.68): C 69.51, H 11.18; found: C 69.60, H 11.29.

S-*Dodecyl* O-*Methyl 2-Methylmonothiosuccinate* (= *Methyl 4-(Dodecylthio)-2-methyl-4-oxobutanoate*; **8b**). As described for **8a**, from methyl hydrogen 2-methylsuccinate (200 mg, 1.4 mmol) and dodecane-1-thiol (606 mg, 2.8 mmol) as described for **8a**. FC (hexane/Et_2O 6:1) afforded **8b** (160 mg, 35%). TLC (hexane/Et_2O 8:1): R_f 0.36. IR: 2935*s*, 2855*s*, 1735*s*, 1682*m*, 1460*m*, 1437*w*, 1380*w*. ^{1}H-NMR: 0.87 (*t*, J = 6.6, 3 H); 1.18–1.40 (*m*, 21 H); 1.20 (*d*, J = 6.99, 3 H); 1.50–1.65 (*m*, 2 H); 2.59–2.68 (*m*, 1 H); 2.87 (*t*, J = 7.35, 2 H); 2.94–3.05 (*m*, 2 H); 3.69 (*s*, 3 H). ^{13}C-NMR: 14.08 (*q*); 16.76 (*q*); 22.66 (*t*); 28.79 (*t*); 28.94 (*t*); 29.08 (*t*); 29.31 (*t*); 29.49 (*t*); 29.54 (*t*); 29.58 (*t*); 29.60 (*t*); 31.89 (*t*); 35.99 (*d*); 46.84 (*t*); 51.91 (*q*); 175.42 (*s*); 197.59 (*s*). MS: 330 (0.6, M^+), 299 (4), 129 (100), 130 (7), 101 (11), 59 (23), 41 (7).

S-*Hexyl* O-*Methyl 2-Methylmonothiosuccinate* (= *Methyl 4-(Hexylthio)-2-methyl-4-oxobutanoate*; **8c**). As described for **8a**: 39% of **8c**. Purified by FC (hexane/Et_2O 6:1). TLC (hexane/Et_2O 6:1): R_f 0.41. IR: 2920*s*, 2855*s*, 1732*s*, 1680*s*, 1460*m*, 1436*w*, 1379*w*. ^{1}H-NMR: 0.87 (*t*, 3 H); 1.10–1.40 (*m*, 9 H); 1.20 (*d*, J = 6.99, 3 H); 1.42–1.60 (*m*, 2 H); 2.50–2.72 (*m*, 1 H); 2.87 (*t*, 2 H); 2.90–3.05 (*m*, 2 H); 3.69 (*s*, 3 H). ^{13}C-NMR: 13.96 (*q*); 16.76 (*q*); 22.47 (*t*); 28.44 (*t*); 28.92 (*t*); 29.45 (*t*); 31.25 (*t*); 35.98 (*d*); 46.82 (*t*); 51.91 (*q*); 175.40 (*s*); 197.56 (*s*). MS: 215 (6), 129 (100), 101 (26), 59 (64), 40 (52), 69 (14). Anal. calc. for $C_{12}H_{22}O_3S$ (246.36): C 58.50, H 9.00; found: C 58.59, H 8.98.

S-*Ethyl* O-*Methyl 2,2-Dimethylmonothiomalonate* (= *Methyl 3-(Ethylthio)-2,2-dimethyl-3-oxopropanoate*; **7d**) *and* S-*Ethyl* O-*Methyl 2-Methylmonothiosuccinate* (= *Methyl 4-(Ethylthio)-2-methyl-4-oxobutanoate*; **8d**). As described for the octadecyl derivatives **7a** and **8a**.

Dimethyl Dimethylmalonate (**9**) *and Dimethyl 2-Methylsuccinate* (**10**). Available by esterification of the corresponding acids.

Catalytic Reactions. A H-type electrochemical cell similar to that reported in [26] was used. The cathode compartment (25 ml) was separated from the anode (5 ml) by a 14 glass frit. Circulation of the electrolyte soln. was achieved by flushing Ar reduced with a *BASF*-BTS catalyst. The solvents were deoxygenated by vibration in an ultrasonic bath for 15 min while bubbling reduced Ar. Irradiation was performed with a 150-W lamp at 30 cm from the mixture, and cooling was done with a fan. The following procedure is a typical one for the catal. reactions: The cathode and anode compartments of the electrochemical cell were filled with deoxygenated 0.1M $LiClO_4$ MeOH/H_2O 4:1 soln. Residual O_2 was reduced by maintaining a −1.0 V potential for 15 min. With the potentiostat off, **1a** (15 mg, 11 μmol) in MeOH (0.5 ml) and **5a** (102 mg, 0.2 mmol) in hexane (0.5 ml) were added, and the potential was set at −0.85 V. The mixture was irradiated for 18 h. The soln. was diluted with H_2O and extracted with Et_2O and the extract washed with H_2O, dried ($MgSO_4$), and evaporated. The residue was dissolved in Et_2O (10 ml) and the products analyzed by GC and GC/MS. Identification of the products was performed by co-injection with the corresponding authentic samples; octadecane was used as internal standard for the quantitative determinations: 24.5 mg of **7a**, 18.6 mg of **8a**, and 39.6 mg of **5a**.

For the reactions with ethyl thioester **5d**, diethylmethylmalonate was used as internal standard.

Hexamethyl c-*Octadecyl* Coβ-{*2-[(octadecylthio)carbonyl]-3-methoxy-2-methyl-3-oxopropyl*}*cob(III)yrinate Perchlorate* (**6a**). The electrochemical cell was filled with deoxygenated 0.1M $LiClO_4$ in MeCN soln. which was kept under reduced Ar at −1.0 V for 15 min. Then **1a** (100 mg, 0.07 mmol) in deoxygenated MeCN (4 ml) was added and the Co^{II} reduced at −1.0 V for 90 min. The soln. turned dark brown. The potential was then set at −0.8 V. Under red light, **5a** (90 mg, 0.18 mmol) was added and the mixture stirred in the dark for 3 h. After evaporation, the residue was dissolved in Et_2O and washed with 0.1M phosphate buffer pH 7. FC ($NaClO_4$-impreg-

nated silica gel, CH_2Cl_2/THF/Et_2O 2:1:1) gave 50 mg (38%) of **6a**. TLC (CH_2Cl_2/THF/Et_2O 2:1:2): R_f 0.58. UV/VIS ($c = 2.9 \cdot 10^{-5}$, CH_2Cl_2): 262 (23448), 296 (21044), 314 (20690), 328 (sh, 18276), 344 (sh, 15172), 416 (8965), 454 (9500), 500 (sh, 4828). IR: 2940*s*, 2860*m*, 1730*s*, 1570*m*, 1490*m*, 1470*w*, 1440*m*, 1130*s*, 1100*s*. ^{1}H-NMR: −0.10 (*s*, 3 H); 0.20 (*s*, 3 H); 0.34 (*d*, $J = 6.5$, 1 H); 0.59 (*d*, $J = 7$, 1 H); 0.84 (*t*, $J = 6.5$, 12 H); 1.15–1.29, 1.29–2.89 (2*m*, 70 H); 1.39 (*s*, 26 H); 1.56 (*s*, 3 H); 1.61 (*s*, 3 H); 1.64 (*s*, 3 H); 1.66 (*s*, 3 H); 1.7 (*s*, 6 H); 2.36 (*s*, 6 H); 2.42 (*s*, 3 H); 2.46 (*s*, 3 H); 3.32 (*s*, 3 H); 3.42 (*s*-overlapped *m*, 5 H); 3.58, 3.61, 3.62, 3.69, 3.70, 3.73, 3.76 (7*s*, 12 MeO); 3.82–3.85 (*m*, 1 H); 3.87–3.94 (*m*, 1 H); 4.01–4.09 (*m*, 4 H); 4.61 (*d*, $J = 9.3$, 1 H); 4.67 (*d*, $J = 9.5$, 1 H); 6.93 (*s*, 1 H); 6.97 (*s*, 1 H). ^{13}C-NMR: 14.06 (*q*); 16.33 (*q*); 16.54 (*q*); 17.00 (*q*); 17.03 (*q*); 18.59 (*q*); 19.64 (*q*); 22.63 (*q*); 25.01 (*q*); 28.52 (*t*); 28.77 (*t*); 28.86 (*t*); 28.92 (*t*); 28.98 (*t*); 29.02 (*t*); 29.23 (*t*); 29.29 (*t*); 29.41 (*t*); 29.44 (*t*); 29.54 (*t*); 29.60 (*t*); 29.64 (*t*, 20× intensity); 31.64 (*t*); 31.66 (*t*); 31.93 (*t*); 32.08 (*t*); 32.21 (*t*); 33.30 (*t*); 45.62 (*s*); 47.06 (*s*); 50.11 (*?*); 51.65 (*q*); 51.67 (*q*); 51.72 (*q*); 51.77 (*q*); 51.87 (*q*); 52.07 (*q*); 52.34 (*q*); 52.46 (*q*); 55.73 (*?*); 59.31 (*s*); 59.34 (*s*); 64.62 (*s*); 65.16 (*t*); 65.28 (*t*); 74.85 (*d*); 74.95 (*d*); 87.47 (*s*); 87.59 (*s*); 98.52 (*d*); 106.91 (*s*); 107.04 (*s*); 108.85 (*s*); 108.93 (*s*); 163.41 (*s*); 164.01 (*s*); 165.81 (*s*); 166.45 (*s*); 167.41 (*s*); 168.77 (*s*); 170.05 (*s*); 170.47 (*s*); 170.66 (*s*); 171.51 (*s*); 171.57 (*s*); 171.63 (*s*); 171.67 (*s*); 171.90 (*s*); 172.77 (*s*); 172.82 (*s*); 172.87 (*s*); 172.96 (*s*); 173.03 (*s*); 173.52 (*s*); 173.68 (*s*); 174.43 (*s*); 176.51 (*s*); 176.68 (*s*); 176.86 (*s*); 177.03 (*s*); 177.41 (*s*); 177.67 (*s*); 192.70 (*s*); 193.83 (*s*). FAB-MS (3-nitrobenzyl alcohol matrix; $C_{93}H_{152}ClCoN_4O_{21}S$, calc. 1788.69): 1688.1 (4, $[M - ClO_4]^+$), 1411.7 (1.5), 1274.5 (100, $[M - ClO_4 - Me_2C(CO_2Me)(COS(CH_2)_{17}Me)]^+$).

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